RADON MEASUREMENT IN DRINKING WATER AND ASSESSMENT OF AVERAGE ANNUAL EFFECTIVE DOSE IN THE WEST REGION OF IRAN

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ABSTRACT

Radon and its decay products are the main source of natural radiation exposure. Alpha particle emissions of radon in drinking water increase the absorbed dose by the respiratory and gastrointestinal systems, which can lead to cancer. The present study is aimed to determine the radon concentration in drinking water of Kermanshah city, Iran. Radon concentrations in water samples from ten regions of the city were measured by the RTM1688-2 radon meter. Tap water samples were taken three times in each region. The annual effective dose to stomach and lungs per person was calculated according to parameters introduced by the United Nations Scientific Committee on the Effects of Atomic Radiation. According to the results, the average radon concentration in drinking water was 2.96±0.966 Bq/L. The annual effective dose to adults due to waterborne radon was estimated to be about 7.4±2.4 µSv/y for lungs and 0.533±0.17 µSv/y for stomach. This study showed that the concentration of radon in drinking water used by people in Kermanshah is lower than the recommended values. The results show no significant radiological risk related to waterborne radon for the inhabitants of the studied regions.

KEYWORDS:
Radon, drinking water, effective dose, Iran

1. INTRODUCTION

Natural radioactive sources are the main exposures of all living creatures, including humans. As the contribution of natural resources in human exposure is estimated 90% [1]. Radon and its decay products are responsible for 50% of the total dose from natural sources [2].

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Radon (^{222}Rn) is colorless, odorless and tasteless, and is considered a noble gas that is naturally radioactive. It is derived from uranium decay present in rocks and soil [3]. Radon is highly soluble in water, thus the radon gas present in the underlying rocky bed can easily pass through the soil and rocks, inevitably entering groundwater sources. Therefore, soil and various types of rock in the earth's crust and groundwater are the main sources of radon gas propagation [4].

Radon gas, that is an alpha particle emitter, can enter tissues through water, food and inhalation and has negative biological effects on such organs [5-8]. Causing lung cancer is the most important hazard of radon to human health [9]. Although high concentrations of radon in groundwater may contribute to radon exposure through ingestion, the exposure risk through inhalation of radon released from water is usually more significant [10]. Unlike indoor radon, in the case of ingested radon, the radiation exposure is mainly due to radon gas itself rather than its progeny [11, 12]. The stomach receives more than 90% of the total effective dose caused by radon ingestion [12]. On account of its potential public health hazard, surveys of radon in water sources have received much attention in recent decades [17-13].

The domestic water of Kermanshah, a city in the west of Iran, is just supplied from groundwater resources (springs and wells). This paper presents the results of measurements of ^{222}Rn concentration in tap water actually used for drinking and other household uses in Kermanshah. We measured the radon concentration in drinking water in the region for the first time.

Radon can enter the human body through ingestion and inhalation, as radon is released from water to the indoor air. Therefore, radon in water is a source of radiation dose to stomach and lungs. The annual effective doses for ingestion and inhalation were calculated according to parameters introduced by the 2000 report of the UNSCEAR [19]. Accordingly, the annual effective doses due to ingestion corresponding to 1 Bq/l, would equal 0.35 µSv/y for infants, 0.26 µSv/y for children and 0.18 µSv/y for adults.

The annual effective dose due to inhalation corresponding to the concentration of 1 Bq/L in tap water is 2.5 µSv/y. The estimated radiation dose to public due to waterborne radon is also presented accordingly.

2. MATERIALS AND METHODS

Based on the water supply situations, Kermanshah city was divided into ten regions (Table 1) and the water was sampled three times in each region in 2014 during two month (January and February). After the water flowed for several minutes, the flow rate was slowed down and the water was allowed to be collected in a conical glass vessel (one-liter flask) covered with foil, in a manner that minimizes turbulence in the water flow. The collected samples were then taken along the ice to the laboratory and were stored at temperatures below 4 ° C [18].

Radon measurements have been carried out using the RTM1688-2 (a portable RTM1688-2 Radon/Thoron Monitor (Sarad, Dresden, Germany). The unit offers a high sensitivity of more than 3 cpm/(kBq/m³) (Fast Mode) obtained from a very small internal volume of only 130 ml. In each measurement, the 500 ml bubbling flask was filled with the water sample and connected to the radon monitor to create a closed air loop (Fig. 1). The air volume of the system circulated through the loop drawn by the internal pump of the radon monitor. The small bubbles transferred radon very efficient because of the large resulting surface of the junction between water and air.

TABLE 1 - The sampling sites of Kermanshah

	Sampling site	Description
1	Taghbostan boulevard	In the north of the city
2	Anahita town	In the northwest of the city
3	Maskan town	In the northeast of the city
4	Zafar town	In the northeast of the city
5	The west part of Parsian Hotel	In the north of the city
6	Azadi square	In the center of the city
7	Kianshahr town	In the east of the city
8	Ferdosi square	In the south of the city
9	Shahrdari square	In the south of the city
10	Dolat Abad town	In the west of the city

3. RESULTS

Radon levels in drinking water of various regions were different (P=0.001). Table 2 shows the average radon concentration in drinking water samples.The minimum and maximum radon concentration in the samples were 1.775 Bq/L and 4.568 Bq/L, respectively. The average radon concentration was estimated to be 2.9±1.06 Bq/L. If the samples from stations 7 and 10 are not considered, it can be observed that the average radon concentration in water samples from the north of the city (3.34±0.94 Bq/L) is more than that of the south (1.95±0.8 Bq/L, P=0.001). The mean annual effective dose due to radon in drinking water to stomach and lungs was found to be 0.533±0.17 µSv/y and 7.4±2.4 µSv/y respectively.

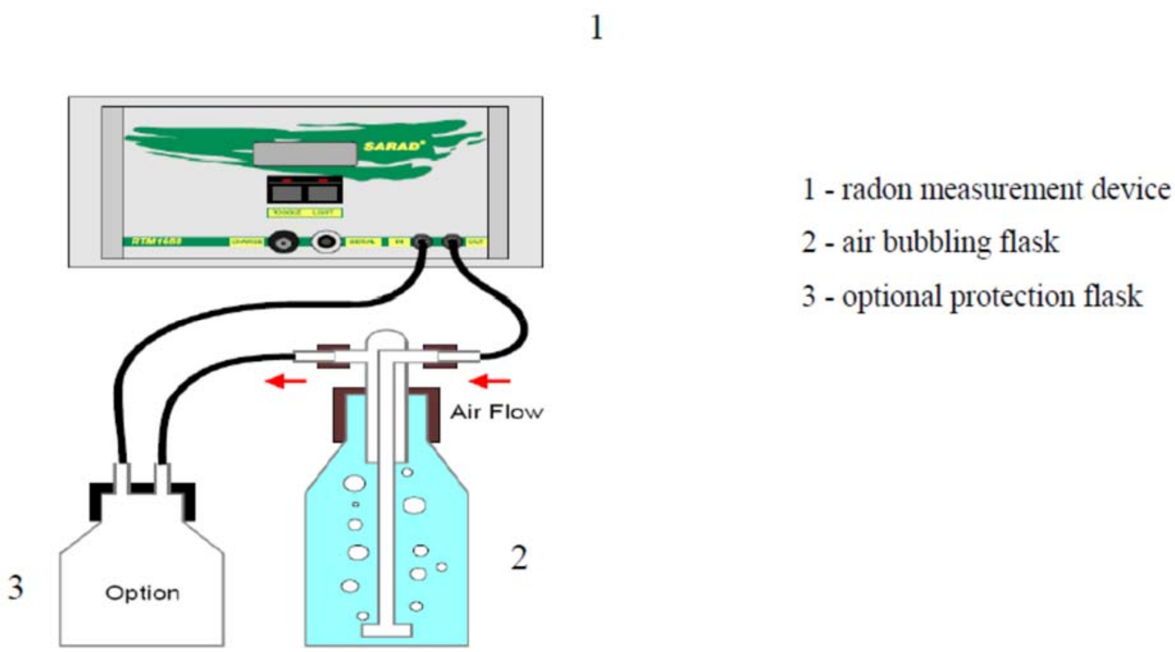

FIGURE 1 -View of radon measurement devices

TABLE 2 - Radon concentration data and annual effective dose of drinking water samples

Sample No.	Place of water sampling	Radon concentration (Bq/L)	Annual effective dose of adults (μSv/y) Stomach	Lung
1	Taghbostan boulevard	4.75±0.07	0.822	11.42
2	Anahita town	4.13±0.43	0.743	10.322
3	Maskan town	2.26±0.25	0.407	5.655
4	Zafar town	3.05±0.91	0.549	7.62
5	The west part of Parsian Hotel	3.13±0.56	0.563	7.817
6	Azadi square	2.2±0.97	0.396	5.5
7	Kianshahr town	2.82±0.57	0.507	7.04
8	Ferdosi square	1.87±0.71	0.336	4.665
9	Shahrdari square	1.8±0.96	0.319	4.437
10	Dolat Abad town	3.8±0.64	0.685	9.52
Average		2.9±1.06	0.533±0.17	7.4±2.4

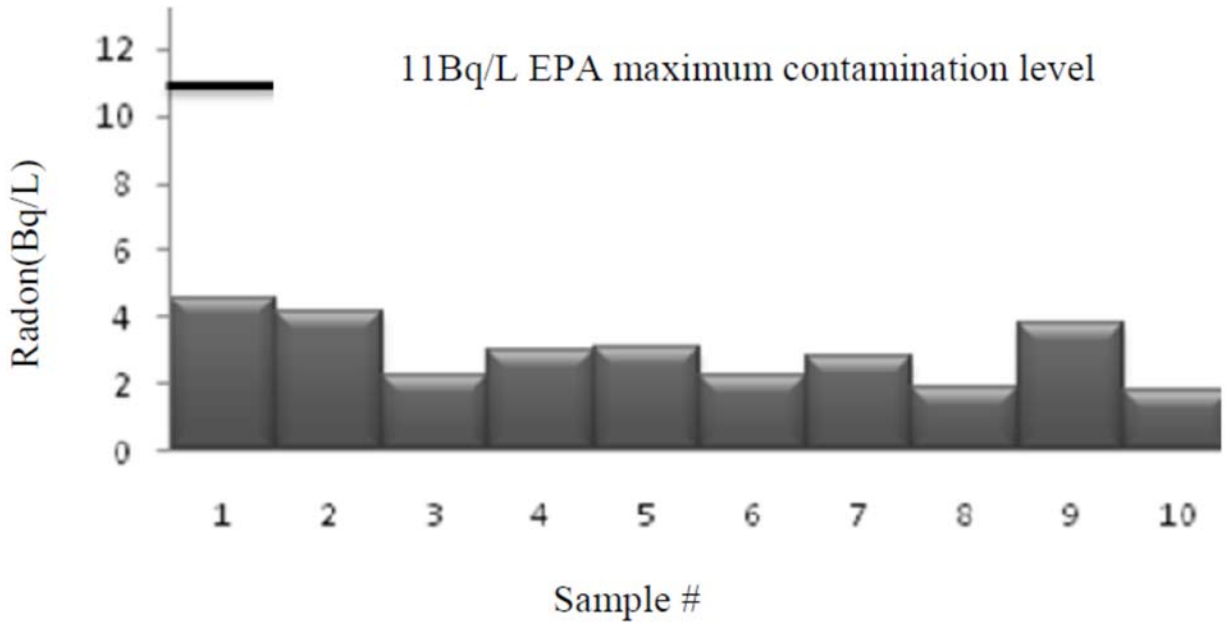

FIGURE 2 - The histogram of radon gas concentration.

4. DISCUSSION

Based on the results, the concentration of radon in drinking water used by the population of Kermanshah city was much less than 11 Bq/L, the Maximum Contamination Level proposed by the U.S Environmental Protection Agency in 1999 [20]. Average annual effective dose caused by waterborne radon to stomach and lungs did not exceed 0.1 mSv/y, the amount recommended by the World Health Organization [21].

The results showed that radon concentration in drinking water of the north of the city was higher than that of the southern regions. Since in areas that are located on a fault line, radon gas emissions into the environment, including groundwater is higher, it seems that the presence of a fault in the northern part of the city causes this difference [22]. In addition water supplies of the southern regions are mainly out of the city (Miandarband wells), while drinking water of the north is primarily supplied from sources located in the north of the city. So the maximum radon concentrations were measured in drinking water of Taghbostan region that is supplied from Taghbostan spring originating from Taghbostan mountain which is in contact with the north fault.

The average radon concentration in drinking water of Kermanshah city was 2.9±1.06 Bq/L that is approximately equal to the amount obtained for radon concentration in drinking water of Ramsar, 3.005 Bq/L [23] and lower than radon concentration in drinking water of Tehran 3.7±0.94 Bq/L [24]. Radon concentrations in drinking water in other countries are summarized in Table 3.

TABLE 3 - Radon activities in drinking water from recent studies

Country	Radon concentration (Bq/L)
Italy [25]	8
Jordan [15]	2.5-4.7
Brazil [26]	0.39-0.47
Saudi Arabia [17]	0.92-2.12
UK [27]	0-2
Venezuela [28]	0-2
Poland [29]	1.7–376; the "medicinal spring water" >74

Groundwater usually contains higher radon concentration than surface water. Because radon present in surface water, such as lakes and rivers, is readily released into outdoor air by agitation of water as it passes over rocks and soils [30]. So differences in the amount of radon in the water may be related to the water source type as well as the presence of active faults.

4. CONCLUSION

Even though the drinking water used by the population of Kermanshah is only supplied from groundwater sources, the results of this study show that there is no significant radiological risk related to waterborne radon for the inhabitants of the studied regions.

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